

2006

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Recommended Citation

Laboski, C. A. M.; Sawyer, J. E.; Walters, D. T.; Bundy, L. G.; Hoelt, R. G.; Randall, G. W.; and Andraski, T. W., "Evaluation of the Illinois Soil Nitrogen Test in the North Central Region" (2006). *Agronomy Conference Proceedings and Presentations*. 48.
http://lib.dr.iastate.edu/agron_conf/48

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EVALUATION OF THE ILLINOIS SOIL NITROGEN TEST IN THE NORTH CENTRAL REGION

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Abstract

Data from 96 locations across the North Central Region was compiled to evaluate the usefulness of the Illinois soil nitrogen test (ISNT) in identifying fields where corn will not respond to additional N fertilizer and predicting the yield optimizing N rate (YONR) for each field. The ISNT could not accurately predict non-responsive sites, nor could it predict YONR. Sub-setting the data based on soil drainage class and previous crop did not improve the predictive capability of the ISNT. The ISNT was related to soil organic matter and was measuring a constant fraction of total soil N. The ISNT is not a meaningful tool upon which N rate decisions should be based.

Introduction

The Illinois soil nitrogen test (ISNT) was initially developed as a means to identify fields where corn would not respond to fertilizer nitrogen (N) addition (Khan et al. 2001). The ISNT is a simplified version of a diffusion technique that determines different forms of N in soil hydrolysates (Mulvaney and Khan, 2001). Using stored samples, Mulvaney et al. (2001) found that N fertilizer response in corn was related to amino-sugar N (ASN); whereby as ASN increased, corn N fertilizer response decreased to zero and remained non-responsive above a threshold ASN value. The ISNT was shown to be strongly correlated to ASN (Khan et al., 2001). Other favorable characteristics of the ISNT that could aid in the adoption of the test are that soil samples could be taken from 0-15 cm at the same time as routine soil sampling (Khan et al., 2001). Also samples could be taken in the spring prior to planting corn or the fall prior to the corn crop (Barker et al., 2006a; Hoef et al., 2001).

More recently, Mulvaney et al. (2005) reported on data from 102 N response studies conducted in 1990-1992 and 2001-2003. In this dataset, 33 sites-years were non-responsive while 69 were responsive. The ISNT correctly predicted 31 of the non-responsive sites; meaning that two sites were predicted as being responsive but were not. The ISNT correctly predicted 50 of the responsive sites; meaning that 19 responsive sites were predicted as being non-responsive. Incorrectly classifying responsive sites as non-responsive could have a large negative economic impact to farmers as yield losses from under fertilization would have occurred. Mulvaney et al. (2005) hypothesized why these 19 failures occurred; however, they did not provide any experimental data to substantiate the hypotheses. Fully understanding situations where the test works well and where it does not is essential to providing growers with criteria for successful use of the test.

The objective of this paper was to compile data on corn yield response to applied N from across the North Central Region and assess the effectiveness of the ISNT in predicting fields where corn will not respond to additional N fertilizer.

Methods and Materials

Data were compiled from studies in Iowa, Illinois, Michigan, Minnesota, Nebraska, and Wisconsin that were conducted as part of the regional CSREES NC-218 project (Assessing nitrogen mineralization and other diagnostic criteria to refine nitrogen rates for crops and minimize losses). Results of some of these studies have been reported/published by Barker et al. (2006b); Laboski, 2004; and Osterhaus (2005). Summary information (previous crop, manure history, soil texture, and drainage class) about the sites in each state is provided in Table 1.

Field experiments consisted of either small plots or field strips where N fertilizer was applied at multiple rates, including a zero check plot N rate and a non-yield limiting rate, and replicated four times. Nitrogen was applied as anhydrous ammonia, urea ammonium nitrate, or urea at preplant, sidedress, or split (starter plus sidedress or preplant plus sidedress). All N applications were made such that N losses were minimal. An adapted corn hybrid was planted at each location. Corn grain yield and moisture were measured in each plot.

In general, soil samples were collected prior to planting at depths of 0-15, 15-30, and/or 0-30 cm and in late spring prior to sidedress N application to a depth 30 cm. However, not all sampling depths were collected at each site. Preplant soil samples were analyzed for $\text{NO}_3\text{-N}$, total N (dry combustion), soil organic matter (loss on ignition), ISNT, and extractable phosphorus, exchangeable potassium, and pH. For all samples, the ISNT analysis was performed at the University of Illinois eliminating potential lab to lab variation in ISNT values. Soil samples taken in late spring were analyzed for $\text{NO}_3\text{-N}$.

Grain yield was adjusted to 15.5 % moisture and corn yield response to applied N was fit to either linear, linear plateau, quadratic, quadratic plateau, or spherical models. The model with the best R^2 for each site was chosen to represent the yield response. The yield optimizing N rate (YONR) was determined for each site using the response model and is the N rate where yield was maximized. Relative yield was calculated as yield of the zero N check plot divided by the yield at the YONR. Nitrogen fertilizer response was calculated as the difference between yield at the YONR and the zero N check plot yield divided by the zero N check plot yield.

Results and Discussion

All relationships between yield and ISNT were explored using ISNT measured on both 0-15 cm and 0-30 cm soil sample depths. There was a strong correlation between ISNT measured at 0-15 cm compared to 0-30 cm (Figure 1). Thus, the only data that will be presented is from the 0-15 cm soil samples because there are more sites with 0-15 cm data.

There was no correlation between the ISNT and relative yield of the check plot ($R^2 = 0.05$) (Figure 2). Nitrogen fertilizer response was not correlated to the ISNT (Figure 3). When the one Illinois site is removed that had a N fertilizer response of 554 %, the correlation between N

fertilizer response and ISNT remained poor and non-significant. The Cate-Nelson procedure (Cate and Nelson, 1971) was used to separate the ISNT values into two categories. While the critical level was calculated, the R^2 was poor for both relative yield and N fertilizer response ($R^2 = 0.11$ and 0.08 , respectively).

While relative yield and N fertilizer response may tell us if the ISNT can be a good predictor of non-responsive sites, the relationship between the ISNT and YONR can tell us if the ISNT can be used to select a rate of N fertilizer to be applied. Figure 4 shows this relationship. While the regression is very significant (P value < 0.001), the R^2 , and thus the predictive value of the relationship, is poor because of the large variability. For example, at an ISNT of 300 mg kg^{-1} the YONR ranges from 0 to 240 kg N ha^{-1} . In an effort to understand whether or not management factors could influence the ISNT and subsequent YONR, the data set was broken down based on soil drainage class and previous crop. Table 2 provides the regression equations for ISNT regressed on YONR for each data subset. The relationship between ISNT and YONR was generally not changed when the data were broken into drainage classes. It is interesting to note that sub-setting the data based on previous crop resulted in even poorer R^2 values compared to the whole data set.

Because of the poor relationships between ISNT and various measures of yield response to applied N in this compiled data set, relationships between ISNT and other soil characteristics were explored. The ISNT was not correlated to net N mineralized and nitrified between the preplant and late spring sampling times (Figure 5). The ISNT was strongly correlated to soil organic matter concentration (Figure 6) over a wide range of soil organic matter concentrations (< 1.0 to > 9.0 %) found throughout the region. Soil organic matter and ISNT were also strongly correlated for soils in New York ($R^2 = 0.89$); as calculated using data provided in Klapwyk and Ketterings (2006). Organic matter is usually strongly correlated to total soil N and this relationship holds true for this study ($R^2 = 0.66$). The ISNT is strongly correlated to total soil N and appears to be measuring a relatively constant fraction of total N (Figure 7). In work published by Khan et al. (2001) and Klapwyk and Ketterings (2005), the ISNT was also correlated to total N, although those authors did not explore this relationship. The slopes of the regression lines for the different data sets are relatively similar. In fact, the 95 % confidence interval for an individual regression line includes the regression lines for the other datasets as well. Thus, the ISNT is measuring a constant fraction of total soil N for a wide range of soils.

Total soil N or soil organic matter are not predictive of the amount of N fertilization needed by a corn crop because these parameters do not reflect the size of the readily mineralizable N pool. The ISNT does not appear to have much predictive capability for determining the N needs of corn. The poor performance of the ISNT occurs because it measures a constant fraction of total soil N rather than a specific fraction of soil N, and is not predictive of the amount of N mineralized during the growing season.

Conclusions

The ISNT is not providing any relevant new information upon which N rate guidelines for corn can be based. The ISNT is measuring a constant fraction of total soil N and is not sensitive to the amount of N mineralized during the growing season.

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Table 1. Previous crop, most recent manure application, soil texture, and drainage class for 96 research sites evaluating the ISNT for the NC-218 project in six states, 2002 to 2005.

State	Total number of sites	Previous crop †				Most recent manure application				Soil texture ‡				Drainage class §			
		C	S	DB	A	1 yr	2-5 yr	ls	l	sl	sil	sicl	cl	p	sp	mw	w
		number of sites															
IA	43	-	43	-	-	2	7	-	4	1	7	29	2	13	5	9	16
IL	5	1	4	-	-	0	1	-	-	-	4	1	-	1	4	-	-
MI	4	-	3	1	-	0	0	-	-	-	2	2	-	2	2	-	-
MN	1	-	1	-	-	0	0	-	-	-	1	-	-	-	-	-	1
NF	34 ¶	13	16	5	-	0	0	5	-	6	16	7	-	-	1	8	25
WI	9	5	3	-	1	0	0	-	-	-	9	-	-	-	-	-	9
Total	96	19	70	6	1	2	8	5	4	7	39	39	2	16	12	17	51

† C, corn; S, soybean; DB, dry bean; A, alfalfa.

‡ ls, loamy sand; l, loam; sl, sandy loam; sil, silt loam; sicl, silty clay loam; cl, clay loam.

§ p, poorly drained; sp, somewhat poorly drained; mw, moderately well drained; w, well drained.

¶ All NE sites were irrigated.

Table 2. Regression equations for the relationship between ISNT and yield optimizing N rate (YONR) as affected by soil drainage and previous crop for 96 research sites evaluating the ISNT for the NC-218 project in six states, 2002 to 2005.

Sites	Equation †	Model P > F	R ²	n
All sites	$YONR = 225 - 0.39x$	<0.01	0.22	96
Well drained	$YONR = 252 - 0.49x$	<0.01	0.21	51
Moderately well drained	$YONR = 220 - 0.51x$	0.05	0.24	17
Somewhat poorly drained	$YONR = 295 - 0.59x$	0.07	0.30	12
Poorly drained	$YONR = 194 - 0.27x$	0.06	0.24	16
Previous crop soybean	$YONR = 191 - 0.28x$	<0.01	0.15	70
Previous crop corn	$YONR = 289 - 0.51x$	0.05	0.21	19
Previous crop dry bean	$YONR = 205 - 0.49x$	0.60	0.07	6

† x, ISNT at 0-15 cm (mg kg^{-1}).

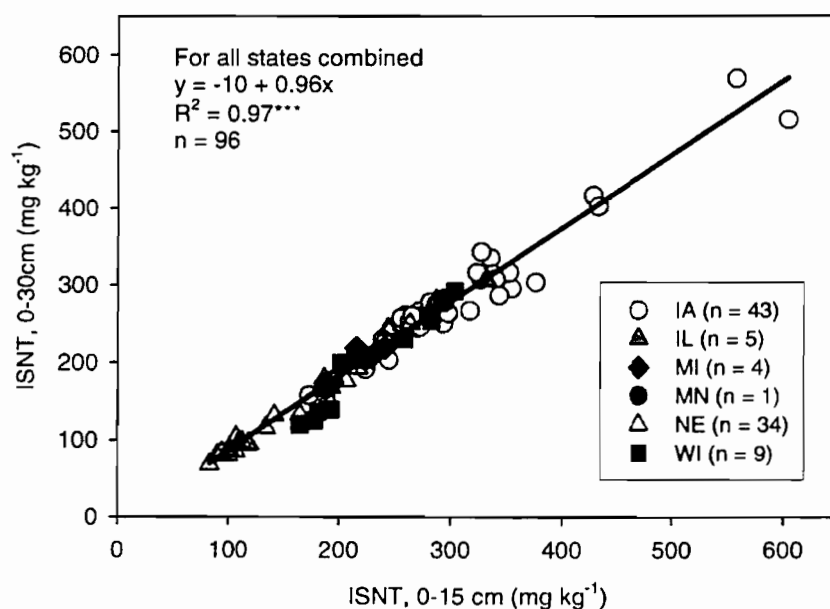


Figure 1. Comparison of ISNT values for 0-15 cm and 0-30 cm soil samples. *** Statistically significant at the 0.001 probability level.

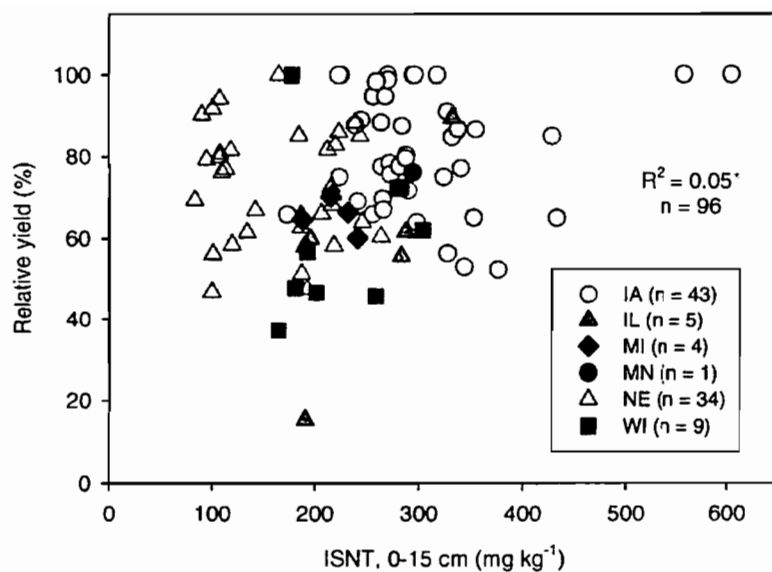


Figure 2. Relationship between the ISNT of soil samples taken preplant to a depth of 15 cm compared the relative yield of the check plot. * Statistically significant at the 0.05 probability level.

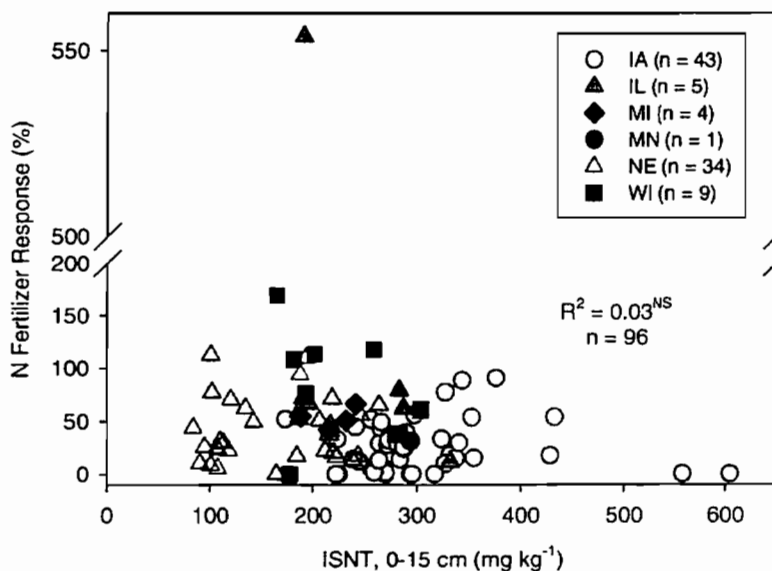


Figure 3. Relationship between ISNT of soil samples taken preplant to a depth of 15 cm compared to N fertilizer response. NS, not statistically significant.

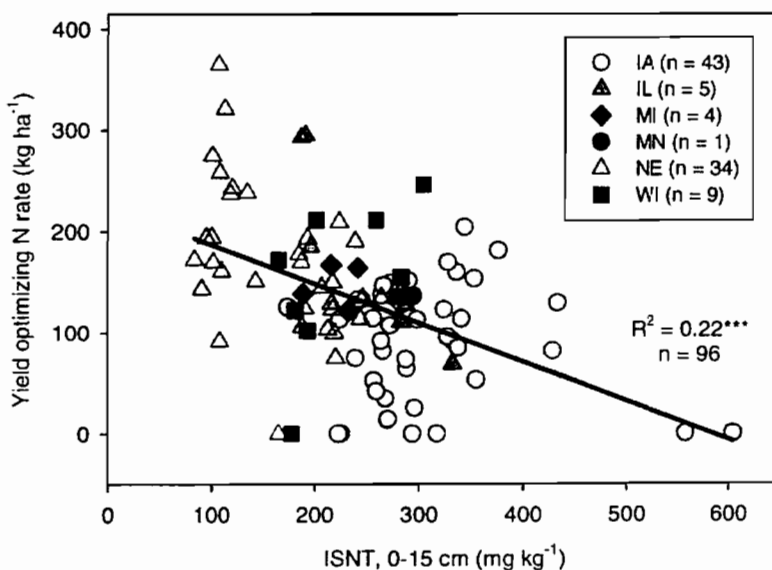


Figure 4. Relationship between the ISNT of soil samples taken preplant to a depth of 15 cm compared to the yield optimizing N rate. *** Statistically significant at the 0.001 probability level.

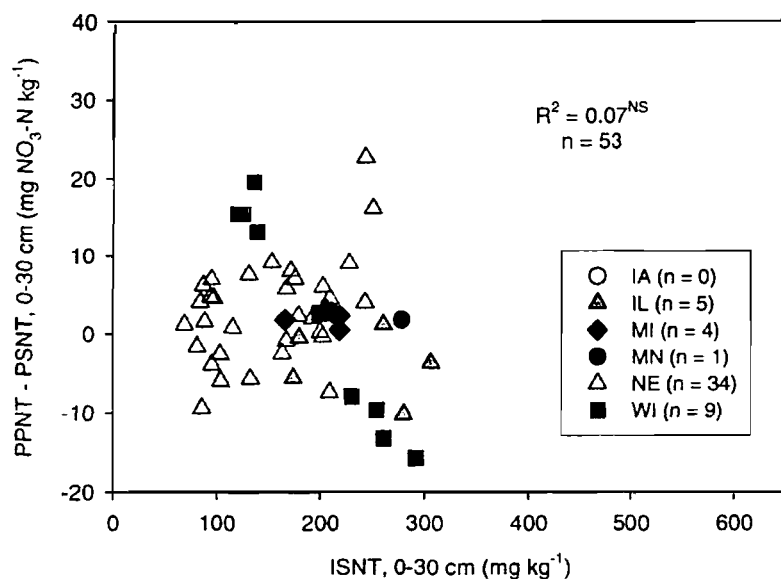


Figure 5. Relationship between the ISNT of soil samples taken preplant to a depth of 30 cm compared to the change in soil nitrate measured in 0-30 cm soil samples taken preplant (PPNT) and in late spring (PSNT). NS, not statistically significant.

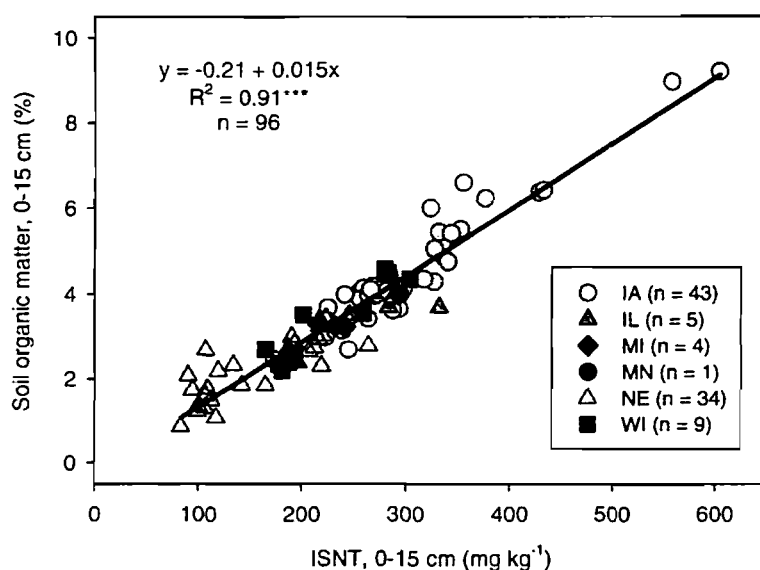


Figure 6. Relationship between soil organic matter concentration and the ISNT measured on soil samples taken preplant to a depth of 15 cm. *** Statistically significant at the 0.001 probability level.

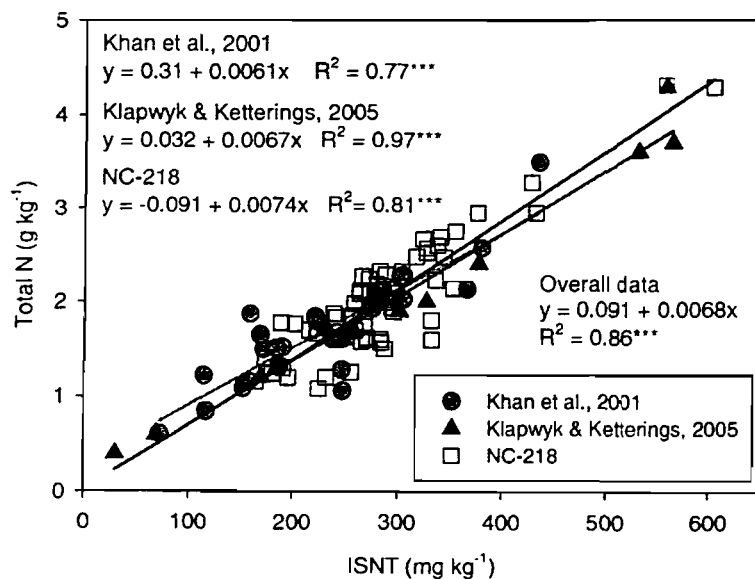


Figure 7. Relationship between ISNT and total soil N measured on the same soil sample. NC-218 data are from the present study. Other data were published by Khan et al. (2001) and Klaywyk and Ketterings (2005). *** Statistically significant at the 0.001 probability level.

PROCEEDINGS OF THE
THIRTY-SIXTH
NORTH CENTRAL
EXTENSION-INDUSTRY
SOIL FERTILITY CONFERENCE

Volume 22

November 7-8, 2006
Holiday Inn Airport
Des Moines, IA

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Published by:

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Web page: www.ppi-ppic.org

Cover photo provided by Dr. Harold F. Reetz, Jr., Monticello, Illinois.